Summary of Oral Presentation/viewgraphs:

The U.S. Department of Energy (DOE), Lockheed Martin (LM), and NASA Glenn Research Center (GRC) have been developing the Advanced Stirling Radioisotope Generator (ASRG) for use as a power system for space science missions. As part of the extended operation testing of this power system, the Advanced Stirling Converters (ASC) at NASA John H. Glenn Research Center undergo a vibration test sequence intended to simulate the vibration history of an ASC used in an ASRG for a space mission. This sequence includes testing at Workmanship and Flight Acceptance levels interspersed with periods of extended operation to simulate pre and post fueling. The final step in the test sequence utilizes additional testing at Flight Acceptance levels to simulate launch. To better replicate the acceleration profile seen by an ASC incorporated into an ASRG, the input spectra used in testing the convertors was modified based on dynamic testing of the ASRG Engineering Unit (ASRG-EU) at Lockheed Martin. This paper presents the vibration test plan for current and future ASC units, including the modified input spectra, and the results of recent tests using these spectra. The test results include data from several accelerometers mounted on the convertors as well as the piston position and output power variables.

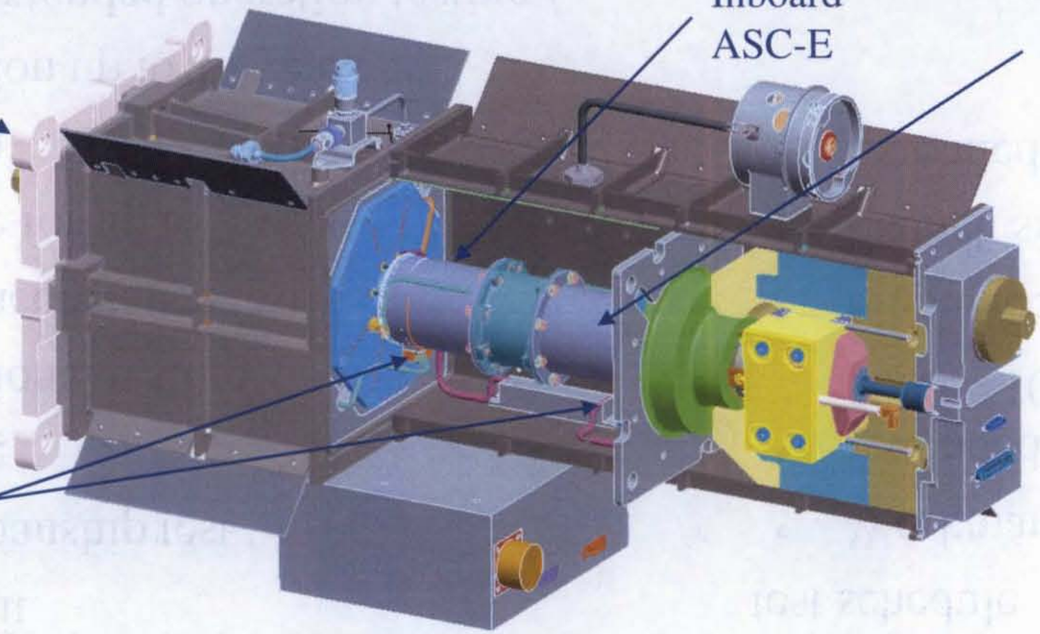
Advanced Stirling Convertor Dynamic Test Approach and Results

David W. Meer — Sest, Inc., Middleburg Heights, OH
Dennis Hill — Lockheed Martin Space Systems Company, King of Prussia, PA
Joseph Ursic — Analex Corporation, Cleveland, OH

Outline

- Objectives of Advanced Stirling Convertor (ASC) dynamic test program
- Advanced Stirling Radioisotope Generator (ASRG) test results
- Test Article
- Test Plan
  - Fixture Characterization
  - Instrumentation
- Vibration Test Results
  - Standard profile input
  - Shaped profile
  - Convertor performance
- Summary
- Conclusions

Introduction – ASRG and Launch Interface



- Nominal 143 We Stirling radioisotope generator; 28 % efficiency @ 20.2 kg
- Spacecraft isolation adapter designed to achieve fundamental generator lateral and axial modes
  - Above spacecraft primary structure / below convertor operation

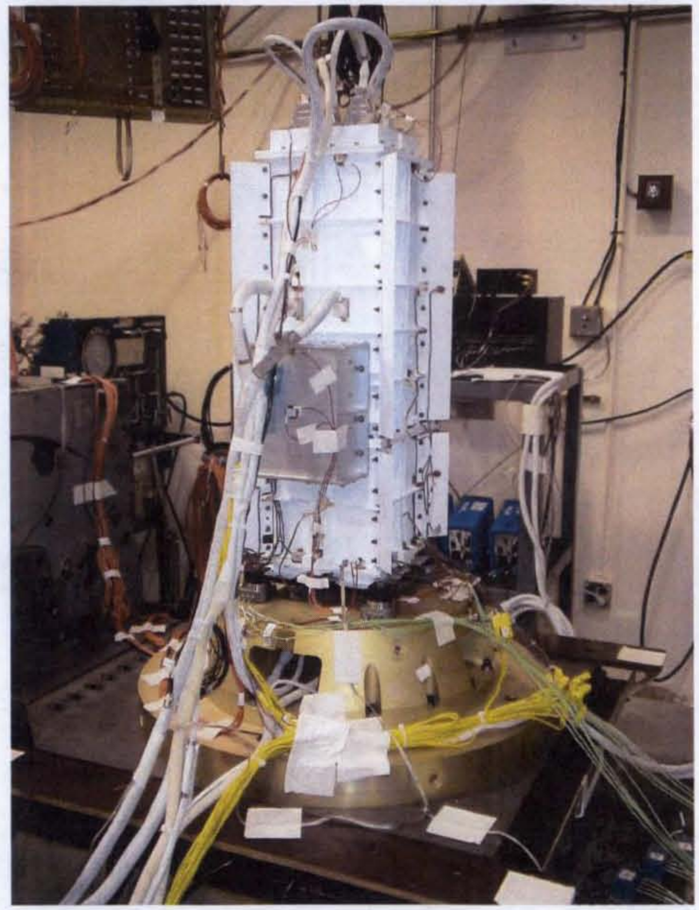
Dynamic Test Program Objectives

- Perform extended life testing of Stirling power systems to demonstrate long term reliability
- Replicate vibration exposure experienced by flight unit
  - Workmanship test
  - Fueling
  - Operational testing
  - Flight acceptance test
  - Storage for up to 3 years
  - Launch
  - Operation up to 14 years
- Maximize extended operation testing / minimize down time

- Extended operation vibration test schedule
  - Workmanship test
  - Extended operation test 5000 – 10000 hours
  - Flight acceptance test
  - Launch simulation
  - Extended operation

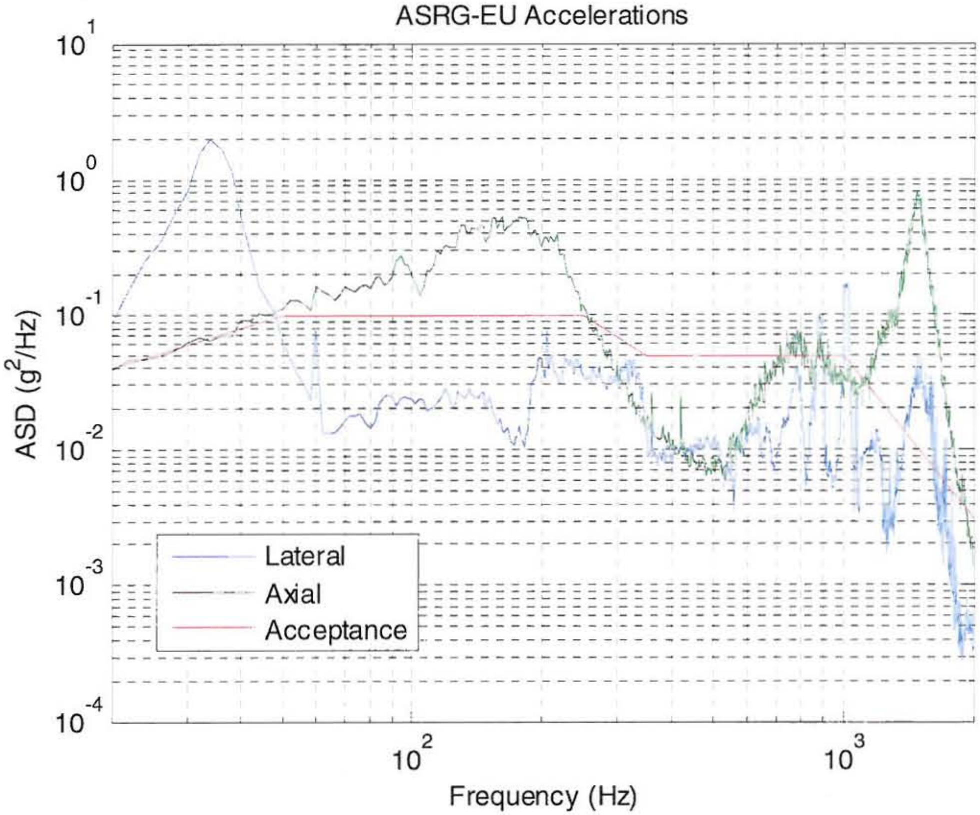
ASRG Engineering Unit (ASRG EU) Dynamic Testing

- Tested to flight qualification levels using JPL RPS standard profile in all three axes
- Axial – in-axis with ASC-E piston motion
- Lateral – 2 axes perpendicular to direction of piston motion
- Instrumentation
  - Internal
    - 2 triaxial accelerometers on ASC-E pressure vessels
    - 8 strain gages on ASC-E heater heads
    - 2 strain gages on ASC-E CSAFs
  - External
    - 22 uniaxial accelerometers
    - 4 strain gages on housing
    - 4 strain gages on S/C isolation adapter



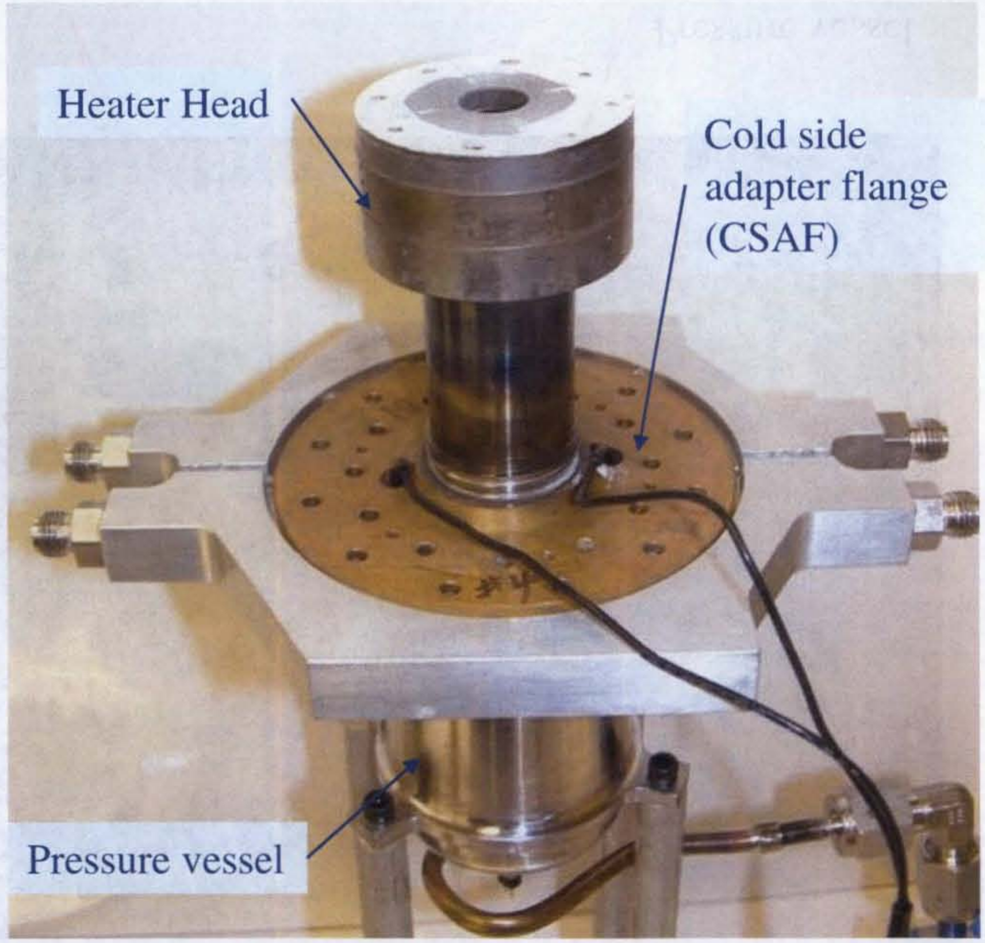
ASRG EU Dynamic Test Results

- Results from ASRG EU testing
- Highest accelerations from both inboard and outboard ASC-E pressure vessel triaxial accelerometers
- Scaled down from qualification level to flight acceptance level (-3 dB)
- Target spectra for life testing for flight acceptance and launch simulation

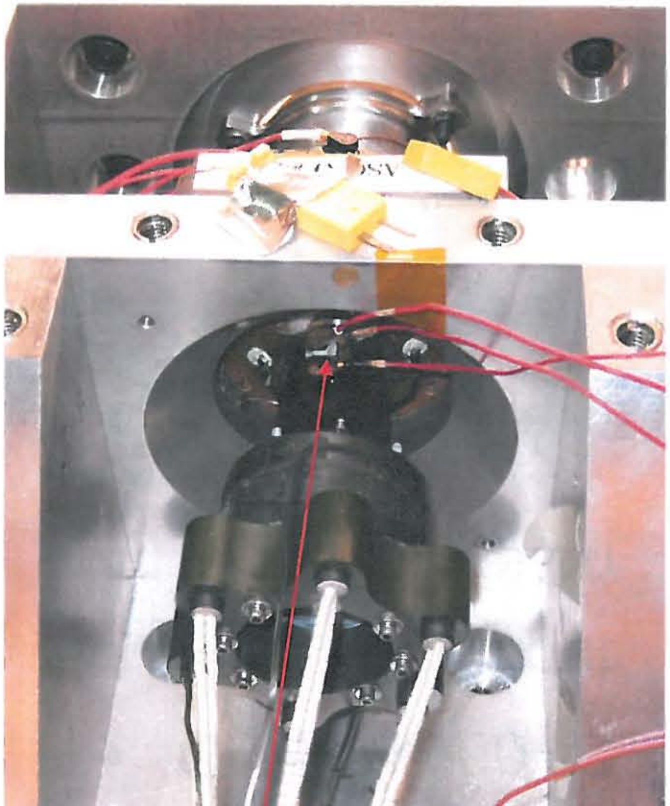


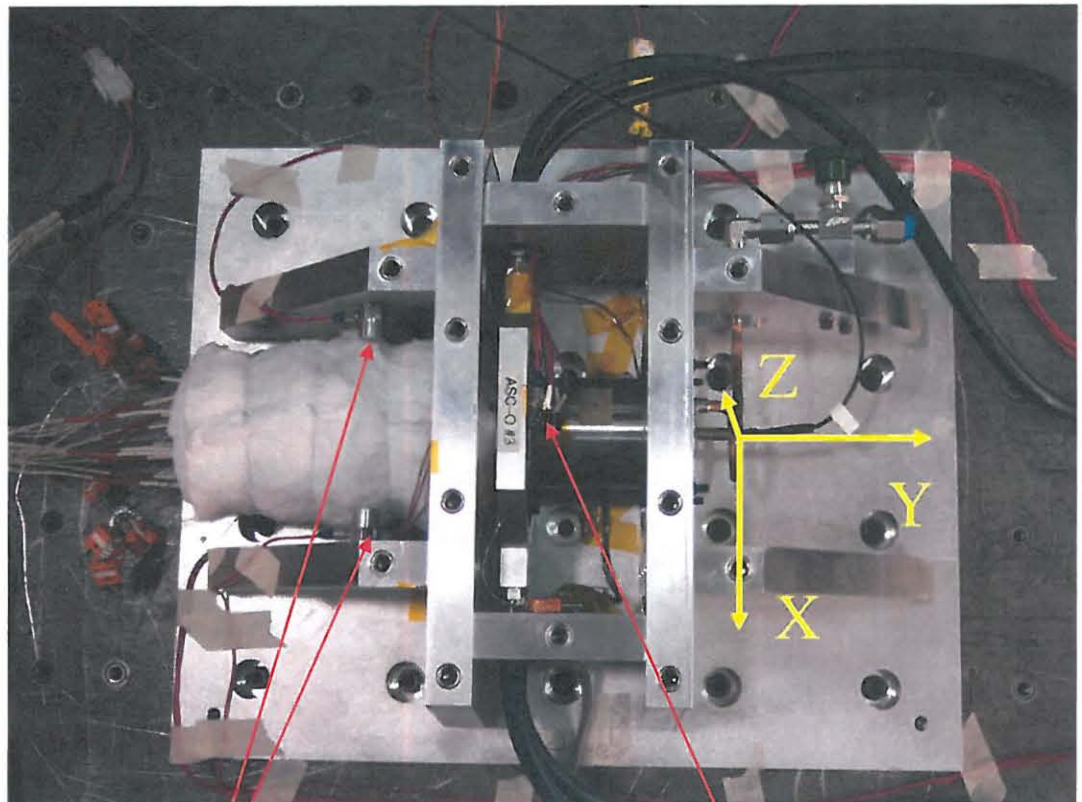
Test Article: ASC-0

- Inconel heater head
  - 625 °C hot-end
- Cold-end 60 °C
- > 70 We output
- 4.40 mm piston amplitude



Test Fixture and Instrumentation





Heater head accelerometer

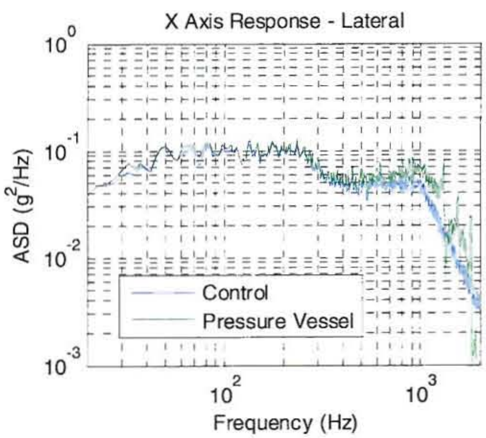
Control accelerometers

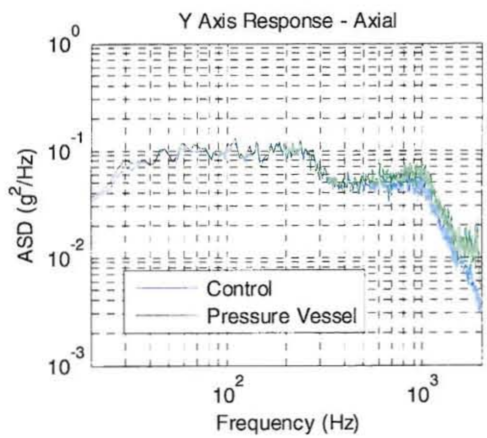
Pressure vessel accelerometer

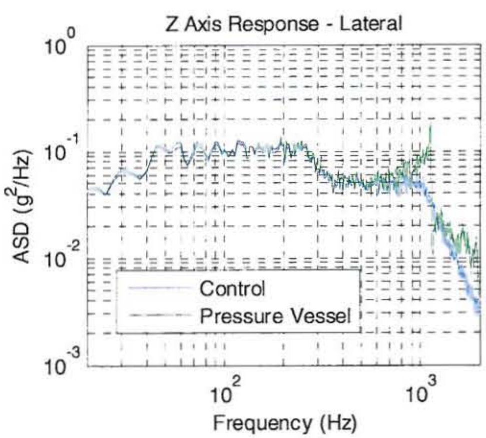
Test Plan

- Fixture characterization
- First convertor
  - Standard RPS profile
  - Sine sweep
  - Flight acceptance
  - Launch simulation
  - Sine sweep
  - X (lateral), Y (axial), and Z (lateral) axes
- Evaluate results
- Second convertor
  - Modified profiles from ASRG EU data
  - Same sequence

First Convertor Results



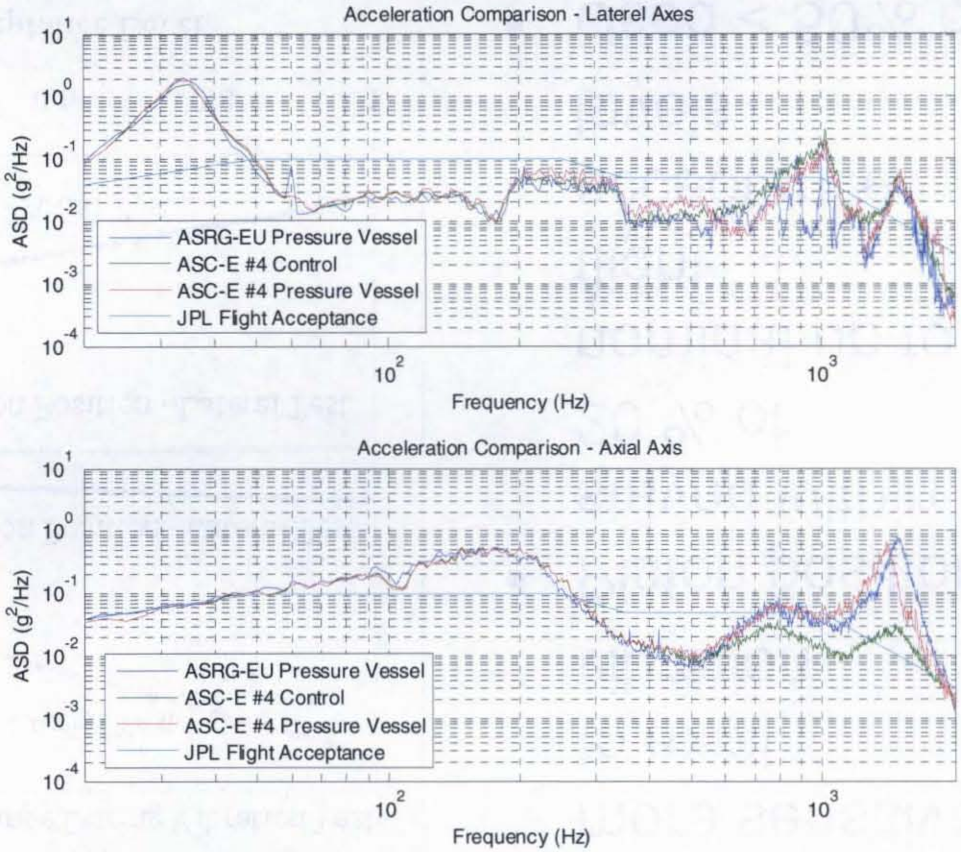




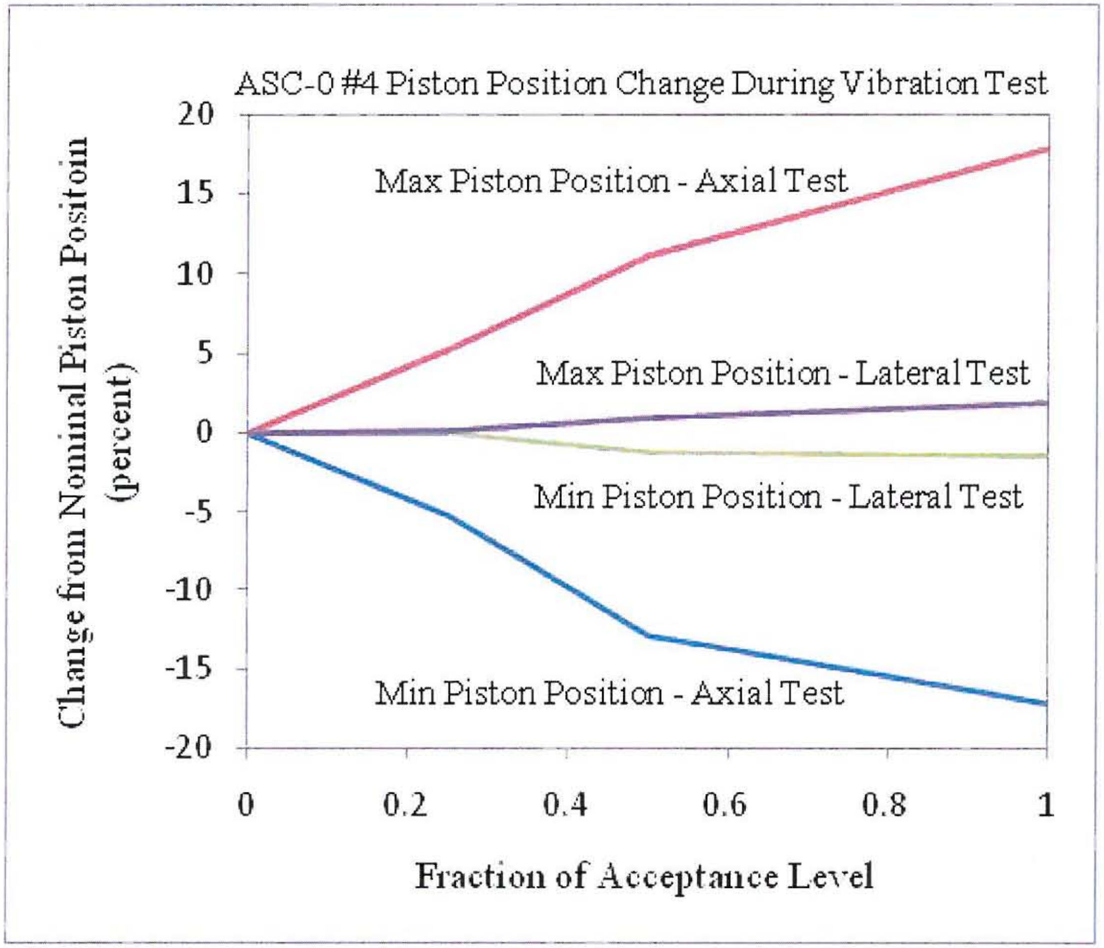
- Standard RPS profile input
- No significant fixture / test article dynamics < 1000 Hz
- Use target spectra as input for next test

Second Convertor Results

- Lateral spectra required little modification to replicate ASRG EU dynamics
- Axial spectra did require a few iterations
- Both match ASRG EU data at pressure vessel

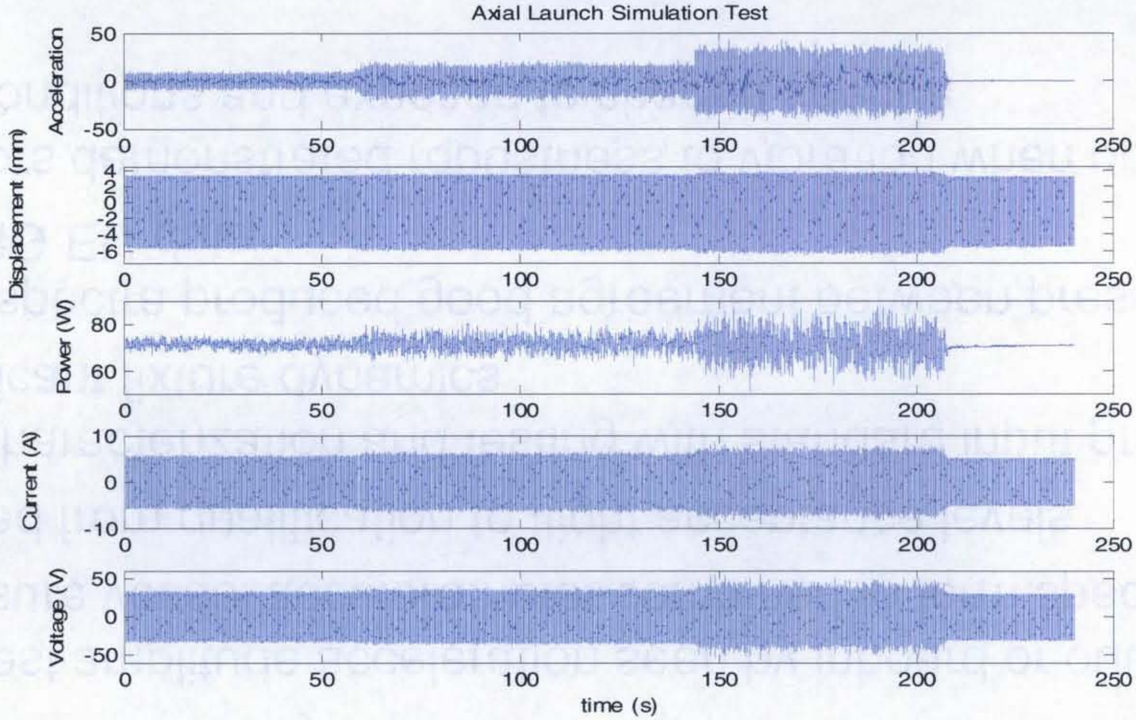


Piston Position Excursions During Vibration



- Convertors more sensitive to axial vibration
- Piston position stayed within 20 % of nominal up to flight acceptance levels
- Used < 50% of safety margin

Convertor Performance During Axial Vibration



- Step up in acceleration (-12 dB, -6 dB, flight acceptance, none)
- Piston position, alternator voltage, and alternator current affected by amplitude of axial vibration
- Convertor performance quickly returns to normal after vibration

Conclusions

- ASC Extended Life Dynamic Test Plan
  - Plan developed to replicate the vibration exposure experienced by a typical flight unit while maximizing extended operation time
- Data collected from dynamic test of ASRG EU
  - Largest amplitude acceleration seen by inboard or outboard pressure vessel accelerometer combined to form spectra
  - Scaled from qualification to flight acceptance levels
- Fixture characterization and testing with standard input profile showed no significant fixture dynamics
- Shaped spectra produced good agreement between pressure vessel and ASRG EU data
- Convertors demonstrated robustness to vibration when operating at launch conditions and exposed to shaped spectra

Acknowledgements

This work was enabled through the Department of Energy (DOE) Stirling Radioisotope Generator (SRG110) program and through NASA Science Mission Directorate Funding. Any opinions, findings, and conclusions or recommendations expressed in this presentation are those of the presenter and do not necessarily reflect the views of the National Aeronautics and Space Administration.

Contributions from:

- Scott Cutlip and Jim Szelagowski – NASA GRC
- Jack Chan – Lockheed Martin
- Rebecca Richardson - DOE
- Jeffery Schreiber and Richard Shaltens - NASA GRC

Questions ?